INSTRUCTION MANUAL

FOR THE

SIGNAL GENERATOR CALIBRATOR

TYPE 245-C

TYPE 245-D

BOONTON RADIO CORPORATION

Boonton, New Jersey

1M/12-59/CP

Printed in U.S.A.

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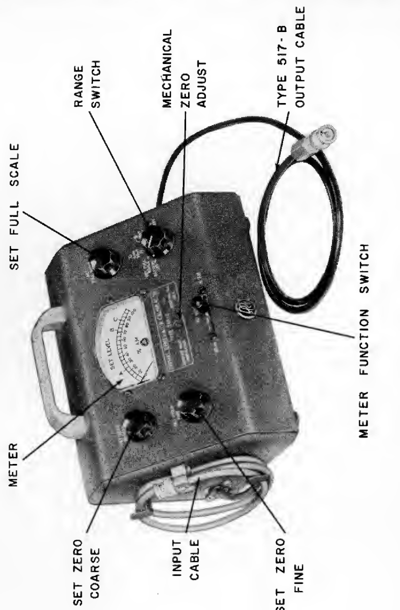


Figure 1. Front Panel Controls

SECTION I
INTRODUCTION

DESCRIPTION

The Signal Generator Calibrator, Figure 1, has been designed to provide a rapid and convenient means for checking and calibrating the rf output and amplitude modulation of signal generators operating in the frequency range of 500 kc to 1000 mc. In addition, the instrument will provide a calibrated low-level rf output for precision testing of receiver sensitivity.

Two models are available; the Type 245-C providing a calibrated rf output of 5, 10, or 20 microvolts, and the Type 245-D providing a calibrated rf output of 0.5, 1, or 2 microvolts. Except for the attenuation ratio of the fixed precision attenuator, the models are identical.

The input is supplied to the instrument through a BNC connector on a 36-inch length of double-shielded coaxial cable having a 50-ohm characteristic impedance. The cable enters through the left side of the cabinet and is an integral part of the instrument.

An rf voltmeter monitors the high-level input voltage to an attenuator system which attenuates the voltage to the microvolt region and delivers accurately calibrated, open-circuit rf voltages to the BNC output jack at the right side of the instrument cabinet. This output jack is equivalent to the front panel output connection of a signal generator having an internal 50-ohm source impedance and an open-circuit voltage of 1, 2, or 4 microvolts for the "D" model and 10, 20, or 40 microvolts for the "C" model.

A BNC plug at one end of the Type 517-B Output Cable provided with the instrument connects to the BNC output jack

on the right-hand side of the cabinet. The other end of the output cable is fitted with a 50-ohm termination, a 25-ohm series resistor beyond the termination, and a BNC output connector which feeds the input of the receiver or other equipment under test. Thus, the source impedance is maintained at 50 ohms and the open-circuit voltage at the end of the output cable is 0.5, 1, or 2 microvolts in the case of the 245-D and 5, 10, or 20 microvolts in the case of the 245-C.

Brackets are provided on the left side and the rear of the cabinet for coiling the input and output cables respectively.

All necessary power for the instrument is furnished by internal mercury batteries which essentially provide "shelf life" because of the extremely low drain of the transistorized circuits.

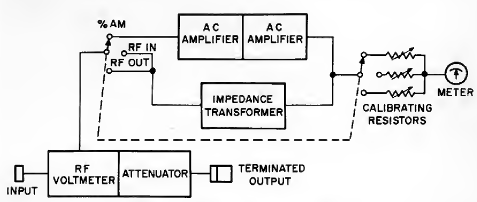


Figure 2. System Block Diagram

APPLICATIONS

The Signal Generator Calibrator will directly measure the rf output of signal generators at 0.025, 0.05, and 0.1 volt. It will also directly measure percent AM from 10 to 100 percent over the modulating frequency range of 20 cps to 20 kc with an rf input level of 0.1 volt.

When supplied from a signal generator or other source of rf voltage, the Signal Generator Calibrator will provide calibrated rf output voltages (at the end the Type 517-B Output Cable) of either 0.5, 1, or 2 microvolts (Type 245-D) or 5, 10, or 20 microvolts (Type 245-C) which may be used directly for the precision testing of receiver sensitivity or, with a receiver used as a level indicator, for calibrating the output of signal generators at these rf levels.

SPECIFICATIONS

Radio Frequency Measurement Characteristics

RF RANGE: 500 kc to 1000 mc

RF VOLTAGE MEASUREMENT LEVELS

Input: 0.025, 0.05, 0.1 v
Output: 5, 10, 20 μv (245-D) *
0.5, 1, 2 μv (245-C) *
* When measured across an external 50-ohm termination at the 245 output jack.

RF VOLTAGE ACCURACY

Input: $\pm 10\%$ 500 kc to 500 mc *
$\pm 15\%$ 500 mc to 1000 mc *
* When supplied from a 50-ohm nominal source with a VSWR <2.

Output: $\pm 10\%$ 500 kc to 500 mc *
$\pm 20\%$ 500 mc to 1000 mc *
* When measured across an external 50-ohm termination at the 245 output jack.

RF IMPEDANCE

Input: 50 ohms
Output: 50 ohms at output jack on instrument and at output connector of Type 517-B Output Cable.

RF VSWR

Input: <1.3 500 kc to 500 mc
<1.6 500 mc to 1000 mc

Output: <1.05 500 kc to 100 mc *
<1.07 100 mc to 500 mc *
<1.1 500 mc to 1000 mc *
* At output connector of Type 517-B Output Cable.

Amplitude Modulation Measurement Characteristics

AM RANGE: 10 to 100%

AM ACCURACY: ±10% 30 cps to 15 kc *
±15% 20 cps to 20 kc *
* Modulating frequency

AM FREQUENCY RANGE: 20 cps to 20 kc

RF INPUT REQUIREMENTS: 0.1 volt

Accessories Furnished: Type 517-B Output Cable

Tube Complement

2 — 1N34A Diode	2 — 2N109 Transistor
1 — 1N415B Diode	1 — 2N647 Transistor

Physical Characteristics

MOUNTING: Cabinet for bench use

DIMENSIONS: Height 6½ inches, width 9¾ inches, depth 6 inches

WEIGHT: 5 pounds

FINISH: Gray wrinkle, engraved panel (other finishes available on special order).

Power Requirements: No external power is required by the Signal Generator Calibrator. All necessary power is furnished by internal mercury batteries.

FRONT PANEL CONTROLS AND INDICATORS

Range Switch (S1): This five-position switch is used to select the various functions of the circuits. The switch positions are:

BATTERY OFF — The internal battery is disconnected. It is in this position that the mechanical zero of the meter should be checked and corrected if necessary.

"A" — In this position the metering circuit is calibrated for 0.025 v input and 0.5μv (245-D) or 5 μv (245-C) output.

"B" — In this position the metering circuit is calibrated for 0.05 v input and 1 μv (245-D) or 10 μv (245-C) output.

"C" — In this position the metering circuit is calibrated for 0.1 v input and 2 μv (245-D) or 20 μv (245-C) output. This position is also used for % AM measurements.

Meter Function Switch (S2): Selects proper circuitry to provide correct calibration for either rf input voltage or rf output voltage. The switch positions are:

RF IN — Meter calibrated for high-level rf input voltage measurements.

RF OUT — Meter calibrated for low-level rf output voltage measurements.

% AM — After the rf carrier level is adjusted to 0.1 v ("C" on the meter) with the Meter Function Switch in the RF IN position, the % AM position is used for direct reading of percent amplitude modulation of a modulated rf input signal at the 0.1-v input level.

SET FULL SCALE (R2): This control is used to adjust the instrument for full scale meter reading when the Range Switch is set in the FULL SCALE position. Clockwise rotation of the control causes the pointer to move to the right.

SET ZERO COARSE (R3A and B) and SET ZERO FINE (R5): Adjusts meter circuit so that meter reads zero with no signal being applied to the input cable. The controls function only

when the Range Switch is set to the "A", "B", or "C" position. Clockwise rotation of the controls causes the pointer to move to the right. The coarse potentiometer will cause approximately 10 times the displacement of the fine potentiometer.

Panel Meter (M1): The Panel Meter has two calibrated scales as follows:

SET LEVEL (Red) Scale — This scale has five calibrated points; the zero or extreme left-hand point, the full-scale or extreme right-hand point, and the "A", "B", and "C" points which correspond to the three rf voltage positions on the Range Switch.

% AM (Black) Scale — This scale is calibrated in 0 to 100 percent AM.

SECTION II

OPERATING INSTRUCTIONS

PRELIMINARY PROCEDURE

If necessary, the mechanical zero of the voltmeter should be adjusted before turning the power on.

Plug the input cable on the Signal Generator Calibrator into the 50-ohm output of the signal generator to be used, and set the Meter Function Switch to the RF OUT position. Turn the Range Switch to the SET FULL SCALE position and adjust the SET FULL SCALE control until the pointer on the voltmeter is aligned with the extreme right-hand calibration mark on the SET LEVEL (red) scale. Clockwise rotation of the SET FULL SCALE control will cause the pointer to move to the right.

With the signal generator output at minimum (<1 μv), set the Range Switch to the desired voltage and adjust the SET ZERO COARSE and SET ZERO FINE controls until the pointer on the voltmeter is aligned with the extreme left-hand calibration mark on the red scale.

MEASURING RECEIVER SENSITIVITY

After the zero and full scale adjustments have been made, as outlined above, increase the signal generator output until the voltmeter pointer is aligned with the calibration mark on the red scale corresponding to the Range Switch setting. For example, if the Range Switch is set in the "A" position, adjust the signal generator output until the voltmeter pointer is aligned with the "A" calibration mark.

The voltage indicated by the Range Switch is then the open-circuit voltage at the end of the output cable, assuming the cable to be lossless. (If the output cable is not attached, the open-circuit voltage at the output jack will be twice the voltage indicated by the Range Switch.)

The sensitivity of a radio receiver has been defined by the Institute of Radio Engineers[1] as the number of microvolts required to produce standard test output when applied to the input impedance of the receiver through the dummy antenna impedance. For a system consisting of a 50-ohm input transmission line and a receiver with a 50-ohm input impedance, this means that a "one-microvolt receiver" will produce standard output when 1 μv is applied across the series combination of the 50-ohm antenna impedance and the 50-ohm input impedance of the receiver. This yields 0.5 μv across the receiver input terminals.

1 "Standard on Radio Receivers" — I.R.E. 1947 (p. 2)

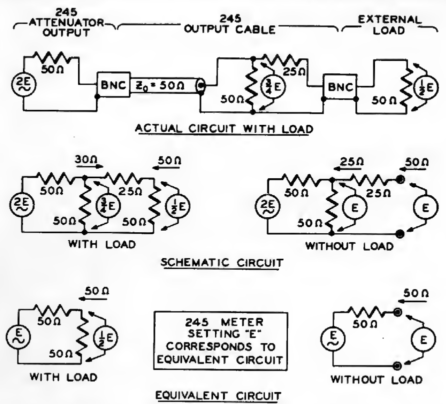


Figure 3. Derivation of Equivalent Circuit of Signal Generator Calibrator Output System Assuming a Matched Load and Ignoring Type 517-B Output Cable Losses

Figure 3 shows how this condition is met by the voltage calibration and output impedance characteristics of the Signal Generator Calibrator when the input voltage is adjusted to produce an indication of 1 μv. The actual circuit can be reduced to the schematic circuit shown because the characteristic impedance of the cable is matched at the voltage source. Under this condition, the length of a lossless cable becomes unimportant and may be neglected. Above 100 mc, however, the loss in small diameter solid dielectric cables is significant and must be taken into account in the measurement. See Section III for

a discussion of cable lengths as a source of measurement error.

The diagrams in Figure 3 show the distribution of voltages and impedances along the schematic circuits for the loaded and open-circuit conditions when the Signal Generator Calibrator indicates Eμv output. The lower set of diagrams shows how the voltage and impedance conditions described above are met by the equivalent circuit.

MEASURING SIGNAL GENERATOR OUTPUT

High-Level Measurements (Direct Reading)

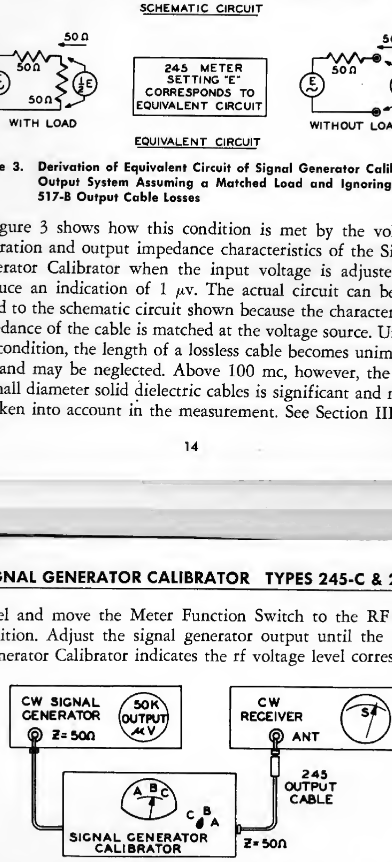
The Signal Generator Calibrator voltmeter may be used to measure the high-level voltage output of signal generators, the losses in the input cable of the instrument being included in the calibration. Set the Range Switch to the desired input voltage level and the Meter Function Switch to the RF IN position. Adjust the signal generator output until the voltmeter pointer is aligned with the red calibration mark corresponding to the Range Switch setting. The voltage indicated by the Range Switch setting is then the voltage at the signal generator output jack.

Low-Level Measurements (Using Receiver As Transfer Indicator)

The use of the Signal Generator Calibrator to measure the low-level output from a signal generator is based on using a receiver as an uncalibrated transfer indicator to compare the outputs from the two sources at a fixed signal level. The receiver used must have good sensitivity, must remain stable in frequency and sensitivity on a short-term basis, and must be equipped with some type of carrier-level meter which can be used as an uncalibrated reference indicator.

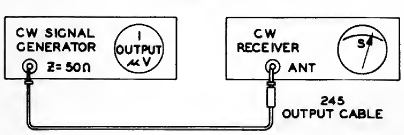
With the Signal Generator Calibrator connected as shown in Figure 4A, set the Range Switch to the desired rf voltage

level and move the Meter Function Switch to the RF OUT position. Adjust the signal generator output until the Signal Generator Calibrator indicates the rf voltage level correspond-



RF VOLTAGE AT HIGH LEVEL IS OBTAINED FROM THE SIGNAL GENERATOR AND ADJUSTED TO GIVE THE DESIRED OUTPUT. THE ATTENUATED OUTPUT IS PICKED UP ON A RECEIVER AND A REFERENCE READING NOTED. CALIBRATION IS IN TERMS OF OPEN CIRCUIT VOLTAGE AT THE END OF THE OUTPUT CABLE.

A



THE LOW LEVEL OUTPUT OF THE SIGNAL GENERATOR IS ADJUSTED TO PRODUCE THE SAME REFERENCE LEVEL READING ON THE RECEIVER AS WAS PRODUCED BY THE KNOWN LOW LEVEL OUTPUT FROM THE SIGNAL GENERATOR CALIBRATOR.

B

Figure 4. Connections for Measuring Signal Generator Output

ing to the Range Switch setting; i.e., the voltmeter pointer is aligned with the "A", "B", or "C" calibration mark on the red scale as determined by the Range Switch setting. Note the carrier-level meter reading.

Disconnect the Signal Generator Calibrator and connect the signal generator directly to the receiver by means of the 50-ohm output cable as shown in Figure 4B. Adjust the signal generator output until the carrier-level meter on the receiver indicates the same reading as was indicated when connected to the Signal Generator Calibrator. The voltage being delivered by the signal generator at the end of the Type 517-B Output Cable is now the same as that delivered by the Signal Generator Calibrator at the end of the same cable.

The method whereby the 50-ohm output cable is switched from the Signal Generator Calibrator to the signal generator is of course valid only for signal generators having a 50-ohm source impedance at the panel output jack. In cases where a signal generator presents 50 ohms at the output end of its own special 50-ohm terminated output cable, the receiver input must be connected to the signal generator output cable. In this way, the comparison will include standing waves on the signal generator output system as well as cable losses.

If the signal generator has a source impedance of 50 ohms, it is not necessary that the receiver input impedance be matched to the signal generator output impedance to obtain a valid comparative reading at the same frequency. Since the two sources of voltage present the same impedance, it is necessary only that the receiver input impedance remain constant, at whatever value it may have, throughout the comparison process. If the signal generator source impedance is other than 50 ohms, corrections must be made in the comparative readings as outlined under the section entitled "Interpretation of Results."

MEASURING PERCENT AM

The Signal Generator Calibrator will read, directly, the percent amplitude modulation of a modulated rf input signal. Before this measurement can be made, however, the unmodulated carrier of the input signal must be set at the 0.1-volt level.

With the Range Switch set to the 0.1 volt ("C") position and the Meter Function Switch set to the RF IN position, adjust the cw output of the signal generator until the voltmeter pointer is aligned with the "C" calibration mark on the SET LEVEL scale. Move the Meter Function Switch to the % AM position and apply the desired modulation to the signal generator. The % AM (black) scale on the voltmeter will now indicate directly the full-wave average of the detected modulation envelope.

PRECAUTIONS

Several points of technique in handling the low-level radio frequencies become of particular importance when checking the output of a signal generator. RF leakage out of the signal generator, sometimes along the power cord, will cause trouble if the receiver is not well shielded. Likewise, interfering signals from adjacent equipment or broadcast transmitters will affect poorly shielded receivers and prevent accurate measurements.

The condition of impedance match and corrections for standing waves on output cables must be accounted for before the performance of a signal generator can be evaluated. The connection between the output cables from the Signal Generator Calibrator and the signal generator to the receiver input should be as short as possible. The insertion loss of any matching pads must be included in the comparison.

Since the diode voltmeter in the Signal Generator Calibrator rectifies all power coming out of the signal generator, including harmonics, excessive distortion in the signal generator rf waveform will introduce errors if the receiver does not also accept all of the energy put out by the signal generator. Sharp receiver response will cause critical tuning and stability problems, and will pass only the low-frequency components of the noise which will cause the meter to bounce. A wider pass band will produce a higher but much steadier noise level to which the desired signal is added.

Always check the signal generator tuning when going from the condition of high level into the Signal Generator Calibrator to low level into the receiver. It is sometimes advisable to retune the signal generator frequency each time the low-level output is readjusted, in order to get reliable results. Line voltage fluctuations during a comparison test will sometimes cause different receiver sensitivities and thereby invalidate the measurements.

When first placing the Signal Generator Calibrator in operation, it is advisable to recheck the SET FULL SCALE and SET ZERO adjustments occasionally. Initial drift can be caused by changes in battery voltage when the instrument is first turned on, and by changes in the resistance of the transistors due to a sudden change in temperature, such as bringing the instrument from storage into a warm laboratory. There is no significant heat developed inside the instrument. Readjusting the SET FULL SCALE and SET ZERO controls restores the calibration accuracy of the instrument even though the transistor and diode dc resistances may have changed.

SECTION III
INTERPRETATION OF RESULTS

SIGNIFICANCE OF OUTPUT READINGS

The equivalent circuit diagrams in Figure 3 show that the same loaded and open-circuit characteristics of voltage and impedance will be presented to the load if a simple series circuit is assumed consisting of an rf generator in series with 50 ohms. The result could have been obtained directly by application of Thevenin's Theorem to the original circuit.

The sensitivity of a receiver designed to work with a 50-ohm antenna line impedance can therefore be read directly on the Signal Generator Calibrator voltmeter at 0.5, 1, and 2 μv on the Type 245-D, or at 5, 10, and 20 μv on the Type 245-C, because the equivalent source impedance of the Signal Generator Calibrator provides the 50-ohm dummy antenna through which these voltages are applied. If higher values of antenna resistance are involved, direct readings of receiver sensitivity can be obtained by merely adding in series with the output cable a suitably mounted, nonreactive resistor equal in value to the desired antenna resistance minus the 50 ohms already presented by the Signal Generator Calibrator. For example, if it is desired to read directly the sensitivity of a receiver designed to operate from a 75-ohm line, a 25-ohm resistor must be added in series with the inner conductor of the BNC output jack on the output cable. This would provide the correct impedance match. If values of antenna resistance less than 50 ohms are involved, it will be necessary to use an impedance matching pad and to allow for insertion loss.

Interpreting the meaning of signal generator output readings becomes more difficult for a signal generator with an output impedance which cannot be made the same as the Signal Generator Calibrator by suitable resistive pads, as shown in Figure 5, or with an output cable system which sets up standing waves at critical frequencies. The same problem is routinely present in the use of such a signal generator for receiver sensitivity measurements. Information required for making corrections in these instances is given in some detail in catalogues and instruction manuals by the major manufacturers of signal generators.

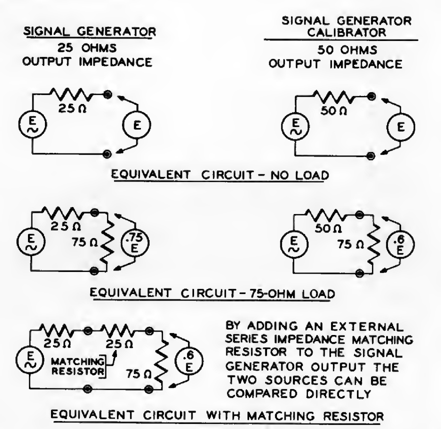


Figure 5. Comparison of Voltage Output from Unequal Source Impedances by Addition of an External Impedance Resistor (Ignoring Type 517-B Output Cable Losses)

Figure 6 shows a case in which the impedance of the Signal Generator Calibrator, the signal generator, and the receiver are 50 ohms, 300 ohms, and 150 ohms respectively. The general equation shown in the figure gives the number of open-circuit microvolts out of the signal generator for any combination of impedances in terms of the indicated output level of the Signal Generator Calibrator output cable as read on the voltmeter.

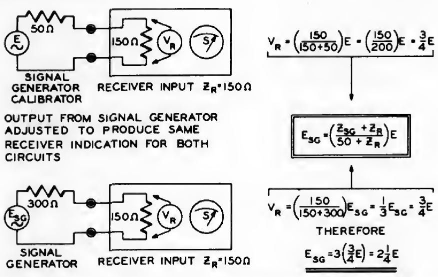


Figure 6. Signal Generator Output Determination When all Three Impedances are Different

Standing waves in the output system of a signal generator, which are not matched internally, will produce errors in calibration which must be accounted for by the use of data supplied in the signal generator instruction manual. These errors are a function of frequency and must be taken into account for each frequency setting.

IMPEDANCE MATCHING

Before attempting to check the output of a signal generator with the Signal Generator Calibrator, determine the output

impedance characteristics of the signal generator. If the impedance is more or less than 50 ohms, attempt to modify the impedance to 50 ohms by means of pads or dummy antenna systems, taking into account their effect on the calibration due to attenuation characteristics. If the signal generator output impedance cannot be made 50 ohms, determine the complex impedance of *both* the receiver and the signal generator and calculate the resulting voltage divider. Since the voltage into the receiver is the same when the signal generator output is adjusted to give the same receiver reading as the Signal Generator Calibrator, we can equate the two expressions as follows:

$$\frac{Z_r}{Z_r + Z_{sg}} E_{sg} = \frac{Z_r}{Z_r + 50} E$$

where: Z_r = receiver input impedance
Z_{sg} = signal generator output impedance
50 = Signal Generator Calibrator output impedance
E_{sg} = signal generator open-circuit voltage
E = Signal Generator Calibrator open-circuit voltage.

Now the open-circuit signal generator output, E_{sg}, which will produce the same receiver response as the output of the Signal Generator Calibrator, E, can be determined from the equation

$$E_{sg} = \frac{Z_r + Z_{sg}}{Z_r + 50} E.$$

SOURCES OF MEASUREMENT ERROR

In addition to the source of error resulting from an unavoidable impedance mismatch, as mentioned above, there are other sources of error in this type of transfer measurement.

Cable Length

It is only necessary to correct for output cable losses when making receiver sensitivity measurements. The loss characteristic of the Type 517-B Output Cable is shown in Figure 7.

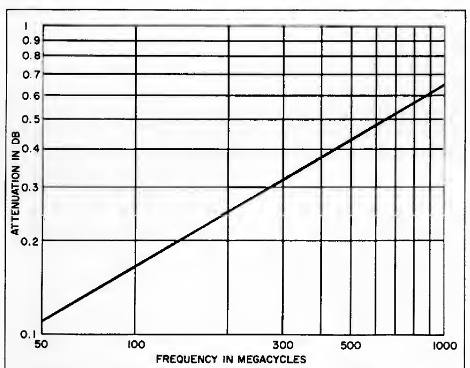


Figure 7. Loss Characteristic of Type 517-B Output Cable

Noise Bandwidth

A secondary source of error is also caused by the output impedance of the generator. If a broad-band system is used as a detector, the effective thermal noise output of the source impedance can be of significant magnitude. For example, if the detector system has a 1-mc bandwidth, a 50-ohm output impedance would generate 0.897 μv. If the output impedance were changed to 52.3 ohms, the thermal noise would be 0.918

μv, equivalent to a 2.3% error. Different source impedances therefore actually generate different open-circuit voltages as measured by a broad-band detector. The difference in noise voltage level is proportional to the square root of the bandwidth and would be small in narrow-band receivers.

Generator DC Resistance

The dc resistance of the signal generator used to drive the Signal Generator Calibrator is part of the dc current return path for the diode voltmeter. The instrument is calibrated for operation with a generator having 50 ohms dc resistance. This value may vary from 20 to several hundred ohms, but radical departures from 50 ohms, such as 0 or infinity, can cause as much as 5% error in the voltmeter calibration.

Generator Leakage

Leakage from the signal generator can cause a serious error in the results. Any signal entering the receiver input from the signal generator which is derived from a source other than through the attenuator system would cause the receiver to read high and give an improper reference. A simple test will aid in determining whether this leakage is independent of the signal generator attenuator setting.

With the signal generator feeding the Signal Generator Calibrator and the Signal Generator Calibrator feeding the receiver, reduce the generator output to a minimum, and then shift the generator frequency. If shifting the frequency does not affect the "S" meter on the receiver, leakage is probably not present. Some generators, however, may leak only when the attenuator is turned near maximum output. This leakage would not be revealed in such a simple check.

The input cable of the Signal Generator Calibrator uses double-shielded coaxial cable because it has been found that single-shielded cable allows excessive leakage. If it is necessary

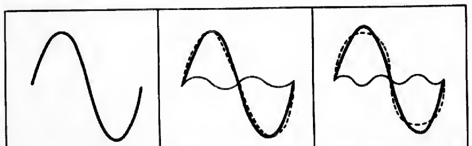
to use an extension on the input cable, a double-shielded cable must be used.

RF Carrier Shift

When making percent AM measurements, users of the Signal Generator Calibrator should be cognizant of a source of error which is not necessarily related to distortion of the modulation envelope; i.e., shift of the average rf level of the modulated signal. This carrier shift may be caused by nonlinear modulation, inverse feedback regulation of the output power level, or poor power supply regulation of the signal generator being used.

Harmonic Distortion

The Signal Generator Calibrator is calibrated for undistorted, sinusoidal modulation. The presence of distortion, therefore, will introduce a corresponding error in the meter indication. If accurate results are required, it is necessary to know the kind and amount of distortion present, and to correct the meter accordingly. An example of the amount of error



	FUNDAMENTAL	10% 2nd HARMONIC	10% 3rd HARMONIC
P.P.V. ERROR		+1.5%	-10%
AVG. V. ERROR		0	+3.3%
METER READING ERROR		-1.5%	+13.3%

Figure 8. Example of Error Caused by 10% Second and Third In-phase Harmonic Modulation Distortion

which would occur from 10% second and third harmonic distortion is shown in Figure 8.

SECTION IV
THEORY OF OPERATION

VOLTAGE MEASUREMENT AND ATTENUATION

The circuit diagram of the rf portion of the attenuator and the output cable system of the Signal Generator Calibrator is shown in Figure 9. Figure 3 shows the distribution of voltages along this cable system under various load conditions, and the resulting equivalent circuit from the rf attenuator output to the end of the output cable.

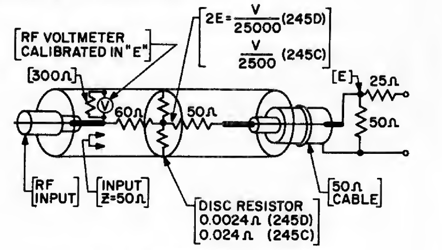


Figure 9. RF Attenuator and Voltmeter

When the Range Switch is set at the "B" position (10-μv level on the 245-C or 1-μv level on the 245-D), and the rf voltage from the external source is adjusted so that the volt-

meter reads at the "B" calibration point, an input level of 0.05 v is established across the input to the coaxial attenuator. In the 245-C, a 2500 to 1 attenuation ratio divides the 0.05 v down to 20 μv which appears across a 0.024-ohm resistor. The attenuator in the 245-D has a 25,000 to 1 ratio which divides the 0.05-v input level down to 2 μv, appearing across a 0.0024-ohm resistor. The low-level voltage in both instruments is in series with a 50-ohm impedance-matching resistor.

Since the 50-ohm characteristic impedance of the output cable is matched by the 50-ohm source impedance, its length is electrically indeterminant and the 50-ohm cable terminating resistor is effectively connected to ground directly from the 50-ohm impedance matching resistor in the rf assembly. This divides down the 20 μv delivered by the coaxial attenuator in the 245-C to 10 μv and the 2 μv delivered by the attenuator in the 245-D to 1 μv; the voltage in both cases being presented across a 50-ohm cable terminating resistor.

RF VOLTMETER

The input voltage to the attenuator is monitored by a semiconductor diode. The simplified circuit of Figure 10 shows the basic dc metering system associated with the rf voltmeter. A frequency compensation circuit, consisting of a low-Q inductive network in series with the rf voltmeter, provides measurements at improved accuracy and eliminates corrections at the higher frequencies where the frequency characteristic of the diode would normally cause increased voltmeter response to the applied voltage.

Tests have shown that the rectification efficiency or ratio of direct voltage output to applied ac voltages of a semiconductor diode at a controlled value of bias current is a very stable characteristic. The justified reputation for instability of semiconductor components is due to changes in resistance

which change the average current or operating point on the rectification curve for a given applied voltage. As long as the average current remains constant and large compared to the rectified component, a given value of rf voltage will produce a constant amount of direct current even though the resistance of the diode may have changed due to temperature or other effects. In the Signal Generator Calibrator, the bias current is always set at the same value during the initial adjustment procedure by means of the SET FULL SCALE control, and therefore the rectification efficiency is a very stable characteristic of the system.

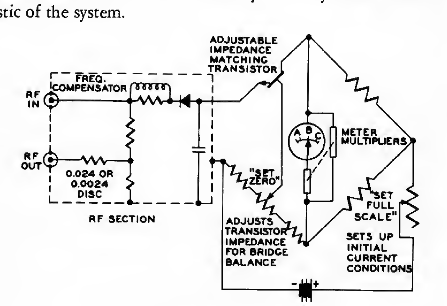


Figure 10. Basic DC Metering System

A common base transistor (Figure 11) is used in conjunction with the diode to raise the impedance level presented to the meter to obtain proper damping. The diode current passes through the junction transistor with a constant efficiency of about 98% regardless of resistance changes. This current transfer factor, known as "alpha", is very stable and therefore

does not contribute any significant variation in accuracy. The function of the transistor is analagous to that of a grounded-grid amplifier in which the current is kept constant while the impedance transformation occurs.[2] The result is that the crystal works into a suitably low impedance while the meter is in series with a high resistance suitable for proper damping.

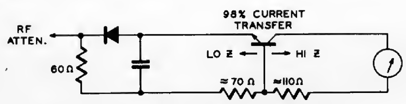


Figure 11. Transistor as Impedance Transformer

DC METERING CIRCUITS

In order to realize the greatest calibration accuracy, each range has only one calibration point. This allows the use of individually adjustable calibration resistors to bring the meter multiplier on each range to the exact value regardless of the meter nonlinearity and attenuator variations.

MICROPOTENTIOMETER TYPE ATTENUATOR

The basic attenuator system consists of a 60-ohm resistor in series with a 0.024-ohm resistor (245-C) or a 0.0024-ohm resistor (245-D), providing a voltage division of 2,500 to 1 and 25,000 to 1 respectively. A 50-ohm resistor in series with the output provides a 50-ohm output impedance.

The 0.024 or 0.0024-ohm resistor is in the form of a concentric disc, consisting of a very thin film of silver, vacuum deposited on a glass base. The disc resistor element is less than half the thickness of the skin depth at 1000 mc. As a

[2]"Principles of Transistor Circuits" — Richard F. Shea (John Wiley and Sons, 1953) p. 5.

result of this characteristic, the current flows uniformly through the film from dc up to 1000 mc, and the series resistance of the disc is essentially the same as the dc value at all frequencies in the range of the instrument. The concentric construction of the disc assures a minimum value of series inductance and, for all practical purposes, the impedance is constant from dc to 1000 mc. A thorough discussion of this type of element is given in a paper by M. C. Selby of the National Bureau of Standards.[3]

RF RESISTORS IN A UNIFORM TRANSMISSION LINE

The 60-ohm series resistor is a very thin evaporated metal film on a glass rod, enclosed in a metal tube of suitable diameter. It can be considered a coaxial transmission line with a resistive center conductor. The choice of constants is such that this line will be 60 ohms, with a very low VSWR, up to 1000 mc.[4] The disc resistor is placed as a "short circuit" at the end of the line.

MODULATION MONITOR

A two-stage transistor amplifier, consisting of two transistors, provides the gain required to read the full-wave average of the detected modulation envelope, when the Signal Generator Calibrator is operated in the % AM position. Inverse feedback is employed in the amplifier to stabilize the gain and improve the linearity of the % AM meter scale. Although the rf detector operates nearly square law, the % AM indication is

[3]"Accurate Radio Frequency Microvoltages," M. C. Selby — Transactions AIEE, May 1953.

[4]"Radio Frequency Resistors As Uniform Transmission Lines," D. R. Crosby and C. H. Pennypacker — Proc. IRE, Feb. 1946, p. 62P.

nearly linear because the AM detector is biased to be always forward conducting. The waveform of the detected modulation versus the modulation envelope is represented in Figure 12. The output polarity of the diode is negative. Referring to

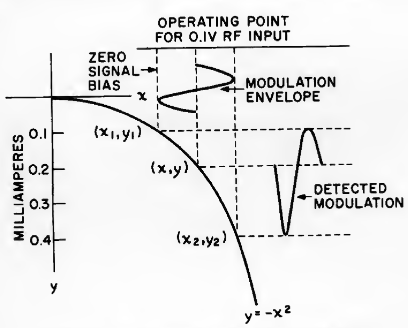


Figure 12. Approximate AM Detector Characteristic

Figure 12, any peak-to-peak limits of the detected modulation are represented as $(y_1 - y_2)$ and the corresponding peaks of the modulation envelope are represented as $(x_2 - x_1)$.

From $y = -x$ (for the square-law diode),

$$y_1 - y_2 = x_2^2 - x_1^2 = (x_2 - x_1)\ (x_2 + x_1)$$

For any given operating point, x, y, $(x_2 + x_1)$ is a constant $(2x)$ since $x + \Delta x + x - \Delta x = 2x$

$$\therefore (y_1 - y_2) \propto (x_2 - x_1).$$

for either distortionless or odd harmonic modulation distortion. Some even harmonic distortion of the modulation envelope is

produced in the instrument as the AM detector law changes near the crests of 100% modulation. This is negligible, however, and is anticipated in the calibration of the % AM scale on the meter. Since the % AM reading is in terms of the full-wave average of the detected modulation, the % AM indication is subject to the usual errors resulting from interpreting peak-to-peak information from an average readout. The Signal Generator Calibrator is provided accurately calibrated for undistorted sinusiodal modulation.

SECTION V
CALIBRATION

FACTORY CALIBRATION

The 60-ohm film resistor together with the 0.024-ohm or 0.0024-ohm disc resistor form an accurate attenuator with a ratio that is carefully measured for each unit. Uniformity of attenuation among the production Signal Generator Calibrators is determined by comparing each unit against a calibrated standard unit at several points over the wide frequency range. The instruments are adjusted to indicate, directly, the voltage at the end of the output cable under no-load conditions over a frequency of 0.5 mc to 1000 mc.

The long-term accuracy, which is of considerably more importance, and upon which the specifications are based, includes the stability of several components not involved in the initial calibration. A circuit has been chosen in which these variations are minimized by the procedure used to place the instrument into operation.

The % AM scale is calibrated by means of a signal from an rf generator accurately calibrated at 25%, 50%, 75%, and 100% modulation at a frequency of 1000 cps with very low envelope distortion. With the signal generator modulation switched off, the input cable on the Signal Generator Calibrator is connected to the output of the signal generator. The Meter Function Switch is set to the RF IN position, the Range Switch is set to the "C" position, and the meter zero is set with the ZERO SET controls. Unmodulated rf is then fed from the signal generator and the generator output is adjusted until the Signal Generator Calibrator meter pointer is aligned with the "C" calibration mark. The Meter Function Switch is then set to the % AM position and the 50% calibrated modulation is fed to the Signal Generator Calibrator from the signal generator. Resistor R22 is adjusted until the meter pointer indicates exactly 50% AM. The instrument is similarly checked at 25%, 75%, and 100%, and accuracy is maintained within 1% of full scale.

FIELD CALIBRATION

The general design of the Signal Generator Calibrator is such that recalibration is seldom necessary. However, if recalibration becomes necessary, it is recommended that the instrument be returned to the factory for the most accurate calibration. If this is not convenient, field calibration of a lesser degree of accuracy may be performed as described below.

Input Voltmeter

Field calibration of the input voltmeter may be accomplished using a low distortion, 1000-cps source having a 50-ohm output impedance, or a signal generator having a piston type attenuator, such as the BRC Types 202-E and 225-A.

To calibrate the Calibrator using the former method, first connect a 60-μf additional bypassing capacitor at the volt-

meter at the end of the coaxial block, then connect the 1000-cps source to the input of the Calibrator through an accurate, high-impedance ac voltmeter. If the output impedance of the 1000-cps source is not 50 ohms, an impedance matching pad should be used. Set the Calibrator Meter Function Switch to the RF IN position and the Range Switch to the "C" position and adjust the level control on the 1000-cps source until the ac voltmeter, connected in the input to the Calibrator, indicates 0.1 volt. Then, adjust resistor R21 (Figure 13) until the pointer on the Calibrator voltmeter is aligned with the "C" calibration mark on the red scale. Repeat the procedure for the 0.05 and 0.025-volt input levels (Range Switch positions "B" and "A") adjusting R18 and R19 (Figure 13) for proper calibration of the voltmeter.

To calibrate the input voltmeter on the Calibrator using an accurate signal generator with a piston type attenuator, connect the output of the signal generator to the Calibrator input. If the output impedance of the generator is other than 50 ohms, a matching pad should be used and the attenuation of this pad should be taken into account when determining the input to the Calibrator as indicated by the signal generator attenuation calibration. With the Meter Function Switch in the RF IN position and the Range Switch in the "C" position, adjust the input signal to 0.1 volt and then adjust resistor R21 (Figure 13) until the Calibrator voltmeter pointer is aligned with the "C" calibration mark on the red scale. Repeat the procedure for the 0.05 and 0.025-volt input levels, adjusting R18 and R19 (Figure 13) for proper calibration of the voltmeter in Range Switch positions "B" and "A". The accuracy of this calibration is, of course, dependent upon the accuracy of the signal generator used. If the accuracy of the generator is dubious, the three levels used in the procedure should be first established by calibrating the generator at these levels with a

bolometer bridge.

Percent AM Meter

The % AM Meter can be recalibrated by comparison with a known percent AM. It is important that the modulation be of low distortion and that there be no carrier shift with modulation. A suitable generator for this purpose is one such as the BRC Type 232-A. If an uncalibrated AM source is all that is available, it may be calibrated using the trapazoidal method. A convenient modulating frequency is 1000 cps and a good calibrating point is 50%. Several points may be checked, if desired, and a compromise setting may be made for any slight error noted. With the Meter Function Switch set to the % AM position and the Range Switch set to the "C" position, adjust resistor R22 (Figure 13) until the meter indicates the correct % AM.

Low-Level Output

When the Signal Generator Calibrator is received from the factory, it is accurately calibrated. It would be advisable at this time to calibrate the high and low-level outputs of several signal generators and to record the information. This data would then serve as a convenient means for checking the calibration of the Calibrator at some later date, if there is reason to believe that its accuracy has deteriorated.

Field calibration of the Calibrator low-level output (attenuation) can be performed easily by direct comparison to a signal generator having an accurately calibrated precision piston attenuator which has been standardized with a bolometer bridge. A sensitive receiver of good signal-to-noise ratio, with a means for indicating relative signal level, is required to monitor the low-level signals.

Connect the signal generator to the receiver and apply a low-level signal of 2 μv or 20 μv (depending upon the model Calibrator being calibrated). Tune and peak the receiver to

this signal and note the relative signal indication on the receiver. Disconnect the signal generator and insert the Calibrator between the generator and the receiver; the input cable connected to the generator and the output cable connected to the receiver. Set the Calibrator Meter Function Switch to the RF OUT position and Range Switch to the "C" position, and increase the generator output until the receiver indicates the same signal level previously indicated. Adjust R20 (Figure 13) until the pointer on the Calibrator voltmeter is aligned with the "C" calibration mark on the red scale.

SECTION VI
FACTORY RECALIBRATION SERVICE

The Signal Generator Calibrator is frequently used as a standard of calibration and inspection. The instruments are carefully calibrated before leaving the factory and tests indicate that the calibration is dependable for a considerable period of time. If indications of calibration errors occur, or if policy dictates periodic recalibration, the instrument may be returned to the factory for recalibration.

Instruments returned for recalibration and/or repair should be carefully packed to eliminate the possibility of shipping damage, and sent, transportation prepaid, to Boonton Radio Corporation, Boonton, New Jersey. A tag, attached to the instrument, should briefly outline the reason for requesting recalibration. Specific services required should be detailed in a separate letter. We will then advise you of the applicable charges and estimated delivery, upon approval of which the necessary work will be carried out.

SECTION VII
BATTERY REPLACEMENT

When it is no longer possible to adjust the meter to full scale as explained in Section II under "Preliminary Procedure", the batteries should be replaced.

Remove the four screws which fasten the rear cover to the instrument cabinet and lay the cover down flat. Remove the two keeper plate elastic mounting nuts and lift the keeper off its mounting studs. Remove the batteries and replace with new General 696 or Eveready E-233 batteries. Replace the keeper plate and mounting nuts, tightening the nuts only enough to hold the batteries firmly in position. Replace the rear cover, being careful that it is right side up and that the battery wires are not pinched between the cover and cabinet.

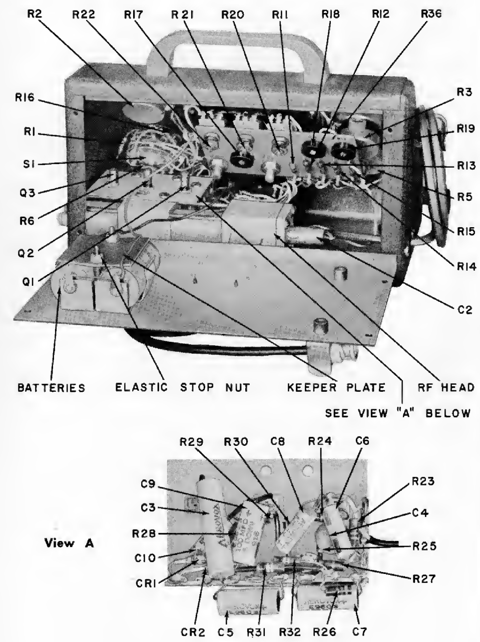


Figure 13. Interior View — Component Layout

SECTION VIII
ELECTRICAL PARTS LIST

Reference Symbol	Value	Description	BRC Part No.	Mfg. Type No.
BT1, 2		Battery, Mercury: 4 volt	303440	Eveready E-233
C1	0.002 μf	Cap., Fixed: ±20%, silver button mica	*82319	Erie 470BH
C2	0.02 μf	Cap., Fixed: +20% — 10%, 600 wvdc, Hypass	*82434	Sprague 79P13
C3	300 μf	Cap., Fixed: —10% + 250%, 3 vdc, Electrolytic	83134	Aerovox PWE3300
C4	0.0015 μf	Cap., Fixed: ±20%, 400 vdc, ceramic disc	82331	Sprague 125L-D15
C5	100 μf	Cap., Fixed: —10% + 250%, 6 vdc, Electrolytic	83133	Aerovox PWE6100
C6	20 μf	Cap., Fixed: —10% + 250%, 6 vdc, Electrolytic	83132	Aerovox PWE6020
C7	100 μf	Cap., Fixed: —10% + 250%, 6 vdc, Electrolytic	83133	Aerovox PWE6100
C8	20 μf	Cap., Fixed: —10% + 250%, 6 vdc, Electrolytic	83132	Aerovox PWE6020
C9	100 μf	Cap., Fixed: —10% + 250%, 6 vdc, Electrolytic	83133	Aerovox PWE6100
C10	10 μf	Cap., Fixed: —10% + 250%, 6 vdc, Electrolytic	83131	Aerovox PWE 6010
CR1, 2		Crystal	91081	Sylvania 1N34A
CR3		Crystal Diode	*91099	Sylvania 1N415B
J1		Connector, BNC	*303430	Indust. Prod. UG-1094/U
L1		Coil, RF: wound on resistot R33	*305973	
M1		Meter: 0-20 μa	*303325	
P1, 2		Connector, BNC	94156	Indust. Prod. UG-88/U
P3		Connector, BNC (output cable termination)	*94156	Special
Q1, 2		Transistor	91097	RCA 2N109
Q3		Transistor	91098	RCA 2N647
R1	580 Ω	Res., Fixed: +1%, 1/2w, Carbofilm	80169	Mepco C15
R2	100 Ω	Res., Variable: +10%, 2w, Comp.	81031	CTS-95
R3A, B	50 Ω	Res., Variable: dual, ±5%, 2w, ww	81029	Clarostat 43
R4	25 Ω	Res., Fixed: ±1%, 1/2w, Carbofilm	80734	Mepco C15
R5	5 Ω	Res., Variable: ±5%, 2w, ww	81030	Clarostat 43
R6	28.1 KΩ	Res., Fixed: ±1%, 1/2w, Carbofilm	80400	Mepco C15
R7	5 Ω	Res., Fixed: ±1%, 1/4w, Carbofilm	**80047	
R8	60 Ω	Res., Fixed: ±1%, 1/2w, Carbofilm	**80728	
R9	50 Ω	Res., Fixed: ±1%, 1/2w, Carbofilm	**80050	
R10	0.024 Ω	Res., Fixed: Annular, silver on glass (245-C)	**306277	
	0.0024 Ω	(245-D)	**306278	
R11	3.3 KΩ	Res., Fixed: ±10%, 1/2w, Carbon	80280	Allen Bradley EB
R12	10.7 KΩ	Res., Fixed: ±1%, 1/2w, Carbofilm	80319	Mepco C15
R13	5 KΩ	Res., Fixed: ±1%, 1/2w, Carbofilm	80302	Mepco C15
R14	28.1 KΩ	Res., Fixed: ±1%, 1/2w, Carbofilm	80400	Mepco C15
R15	16 KΩ	Res., Fixed: ±1%, 1/2w, Carbofilm	80323	Mepco C15
R16	100 Ω	Res., Fixed: ±1%, 1/2w, Carbofilm	80733	Mepco C15
R17	1 KΩ	Res., Variable: ±20%, 1/10w, Comp.	81121	Centralab 1
R18, 19	25 KΩ	Res., Variable: ±20%, 1/10w, Comp.	81420	Centralab 1
R20, 21, 22	250 Ω	Res., Variable: ±10%, 1/2w, Comp.	81075	CTS-X3530
R23	560 Ω	Res., Fixed: ±5%, 1/2w, Comp.	80136	Allen Bradley EB
R24	560 KΩ	Res., Fixed: ±5%, 1/2w, carbon	80629	Allen Bradley EB
R25	10 KΩ	Res., Fixed: ±5%, 1/2w, Comp.	80361	Allen Bradley EB

R26	270 Ω	Res., Fixed: ±5%, 1/2w, carbon	80232	Allen Bradley EB
R27	1 KΩ	Res., Fixed: ±5%, 1/2w, Comp.	80148	Allen Bradley EB
R28	5.6 KΩ	Res., Fixed: ±5%, 1/2w, Comp.	80376	Allen Bradley EB
R29	270 KΩ	Res., Fixed: ±5%, 1/2w, carbon	80604	Allen Bradley EB
R30	1 KΩ	Res., Fixed: ±5%, 1/2w, Comp.	80148	Allen Bradley EB
R31, 32	10 KΩ	Res., Fixed: ±5%, 1/2w, Comp.	80361	Allen Bradley EB
R33	75 Ω	Res., Fixed: ±5%, 1/2w, Comp. (w/coil L1)	*305973	
R34	25 Ω	Res., Fixed: ±1%, 1/8w, Carbofilm (517-B Output Cable)	80056	Electra DC1/8
R35	50 Ω	Res., Fixed: ±1%, 1/8w, disc (517-B Output Cable)	80052	Mepco C343
R36	10 KΩ	Res., Fixed: ±5%, 1/2w, Comp.	80361	Allen Bradley EB
S1		Switch, Rotary: 3-section, 5-position	303355	
S2		Switch, Lever: 3P3T, 1 pole shorting, 2 poles nonshorting	88084	Mallory

*Replacement of these parts requires complete recalibration of the instrument.
**Replacement of these parts can only be performed at our factory.

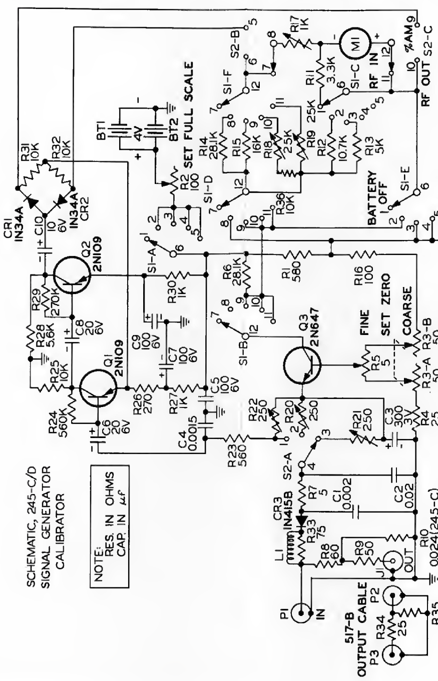


Figure 14. Schematic Diagram — Type 245-C and 245-D